Activation of the aluminium target by 200 MeV/u uranium beam *

P. Katrik[1,2,#], D. Hoffmann[1,2], E. Mustafin[2], and I. Strasik[2]
[1]TU Darmstadt, Darmstadt, Germany; [2]GSI, Darmstadt, Germany

Introduction

The paper presents new results of experimental study of the residual activity induced by high-energy heavy ions in common accelerator constructing materials. This study is a part of a broader research activity for validation of Monte Carlo codes and data libraries. There are several publications reporting the activation of different targets by various heavy ions with energies from 500 MeV/u up to 1 GeV/u [1-4].

Experiment and Simulation

The experimental target was designed in the stacked-foil geometry of 70 pieces. The foils were aluminium discs with the thickness of t = 0.1 mm and diameter d = 10 cm. The target was irradiated by 200 MeV/u $^{238}U^{(+73)}$ beam. The total number of projectiles accumulated on the target was 2.8×10^{12} ions. Gamma-ray spectra of each foil were measured individually or in groups of 5 foils together. Two series of measurements were performed: ~6-20 days and ~130-180 days after the end of irradiation. The experimental data were compared with the Monte Carlo simulations by FLUKA 2011.2c.0 code [5]. The residual activities were recalculated to the end of irradiation.

Results and Discussion

Out of all nuclides observed in the spectra we present here only the results for ^{7}Be, ^{22}Na and ^{237}U.

The distribution of ^{237}U (see Table 1) in depth could be used for finding the range of primary ^{238}U ions, because the masses of these nuclei are almost equal [4]. The FLUKA code predicted presence of ^{237}U in only two foils (Nr. 34 and Nr. 35), but we measured activity of this nuclide in the foil Nr. 36 as well. The simulation expects shorter range and about 40% lower production of ^{237}U.

Table 1: Total activity produced by ^{237}U in Al target

Foil Nr.	Depth [mm]	Activity of ^{237}U produced in target [Bq/mm/ion]	
		Simulation	Experiment
34	3.35	$1.262\times10^{-8} \pm 1\times10^{-10}$	$1.546\times10^{-9} \pm 2\times10^{-11}$
35	3.45	$2.710\times10^{-8} \pm 1\times10^{-10}$	$6.276\times10^{-8} \pm 7\times10^{-11}$
36	3.55	0	$3.461\times10^{-9} \pm 2\times10^{-11}$
SUM of Activity:		**$3.973\times10^{-8} \pm 2\times10^{-10}$**	**$6.776\times10^{-8} \pm 8\times10^{-11}$**

The depth profiles of ^{7}Be and ^{22}Na are presented in Figure 1 and Figure 2, respectively. The simulation is in agreement with the 1st and 2nd set of measurement only in the first foils of the target. In the depth of about 1.25 mm (the vertical line 150 MeV/u) differences between simulation and experimental data become evident. The disparities between the 1st and 2nd set of measurement in the range area are caused due to decaying of short-living isotope which was influencing the 1st set of measurement. In the range area the simulation should be compared with the 2nd set of measurement. One may observe an overestimation of the residual activity in the simulation data.

We observed the discrepancy (of the production of the nuclides in the target) between simulation and experimental data starting from the energy of the primary particles slowed down to 150 MeV/u and/or lower. The biggest difference in the case of ^{7}Be is in the depth corresponding to the primary particle energy of 125 MeV/u (see Figure 1). That is exactly the energy of the change between two Nucleus-Nucleus interaction models in FLUKA code (from Relativistic Quantum Molecular Dynamics for higher energies to Boltzmann Master Equation for lower energies) [5].

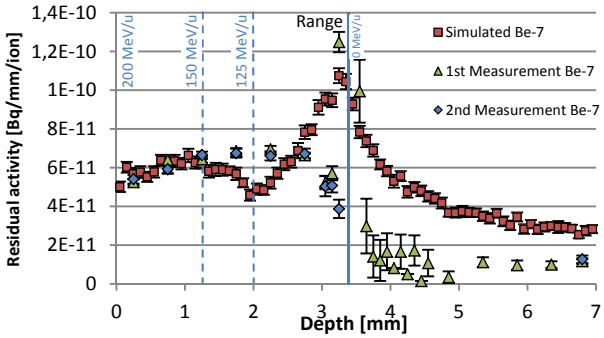

Figure 1: Depth profile of the residual activity of ^{7}Be.

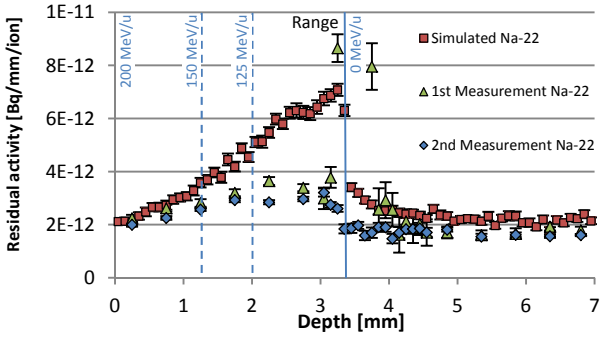

Figure 2: Depth profile of the residual activity of ^{22}Na.

References

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#p.katrik@gsi.de